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Packet Radio Temporary Note #169

PACKET RADIO COMMUNICATION PROTOCOLS

(THIS PACKET RADIO NOTE IS BEING PREPARED AS

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1.1 HIERARCHICAL DATA COMMUNICATIONS PROCEDURES

An abstract "data communication system" consists of "entities" which "transmit" and "receive" "messages" using an abstract "channel" (Figure 1.1). Three types of procedures are required in a data communication system:

A. "Channel operation procedures",

B. "Channel validation procedures", and

C. "Channel initialization and maintenance procedures".

The channel operation procedures allow entities to transmit and receive messages to and from other entities via the channel (open loop). Channel validation procedures maximize the reliability of communication on the channel by doing some or all of the following:

A. Guarantee that at least one way of a message sent from one entity to another in fact arrived;

B. Throw away duplicate copies of messages;

C. Guarantee that a "message" that is received is the same as the one sent;

D. Regulate the flow of messages so that neither the receiving entities, nor the channel are overloaded;

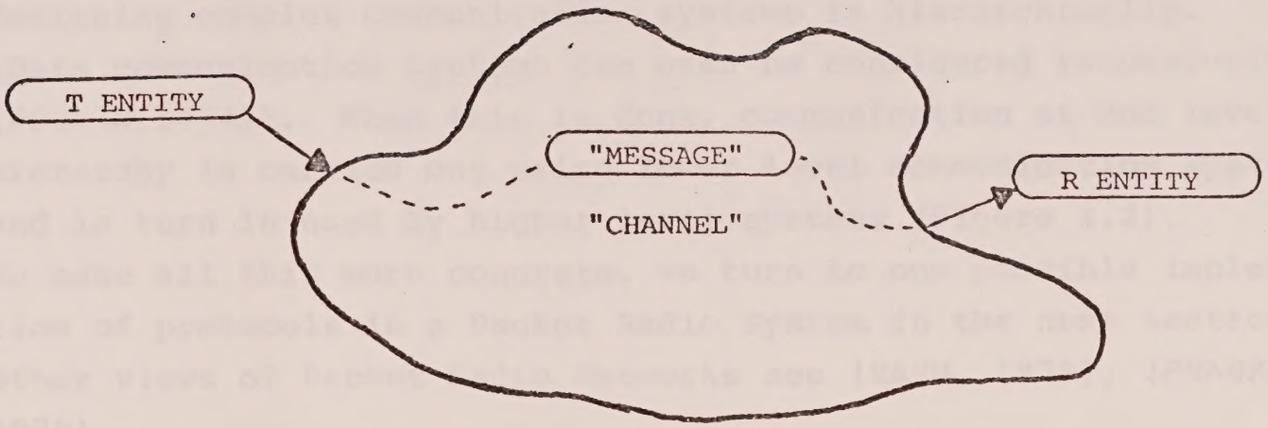

FIGURE 1.1: ABSTRACT DATA COMMUNICATION SYSTEM

E. Maintain sequencing of messages, if necessary.

Finally channel initilization, monitoring, measurement and maintenance procedures provide for the integrity of the channel.

Progressively, as modern data communications systems get larger they get more complex. A profitable way of analyzing and designing complex communication systems is hierarchically. (Data communication systems can even be considered recursively [POUZIN,1974]). When this is done, communication at one level in the hierarchy is carried out using lower level communication systems and in turn is used by higher level systems (Figure 1.2). To make all this more concrete, we turn to one possible implementation of protocols in a Packet Radio System in the next section. For other views of Packet Radio Networks see [KAHN, 1975], [FRANK, 1975].

The Packet Radio System described here differs in some ways both in objectives and details of implementation from the actual Packet Radio System being implemented by ARPA. The hierarchy we define is topological; that is, in the network of channels and switches which make up the system. Other partitions of communication procedures are possible and should not be confused with the one proposed here. For example, the partition could be according to levels of software in implementing computational devices, switching computers and the like; that is if a procedure "calls" another procedure the first is higher than the second in the hierarchy. A hierarchy defined along these lines is usually a refinement of a hierarchy defined in terms of communication function.

In a hierarchally structured communication system not all the validation functions need be performed at every level. Error checking, acknowledgments, sequencing and flow control are validation functions which can be performed at every level of a communications

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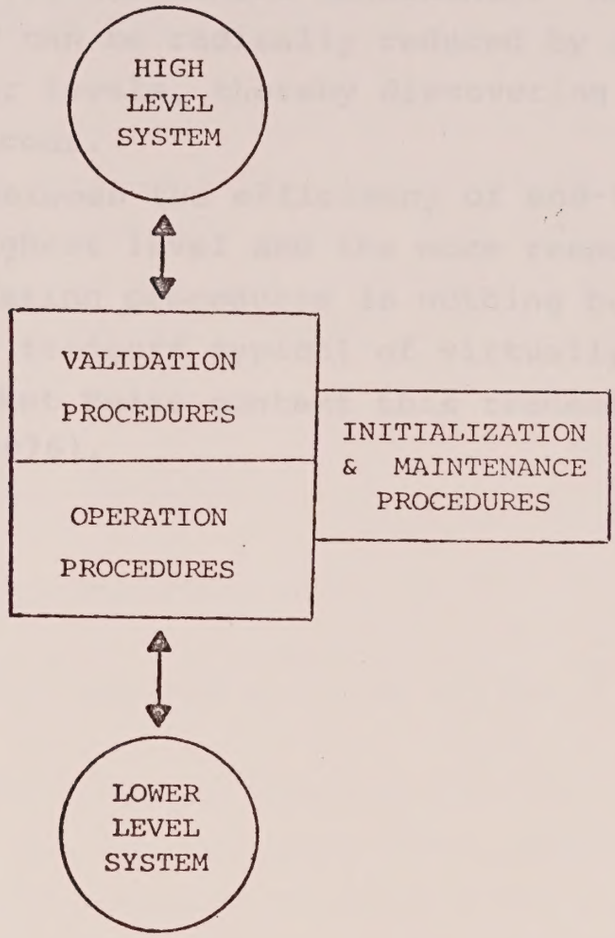

FIGURE 1.2: HIERARCHICAL DATA COMMUNICATION PROCEDURES

hierarchy. For acknowledgments, an end-to-end acknowledgment at the highest level gives the utmost confidence. However, in unreliable systems delay can be radically reduced by acknowledgment verification at lower levels, thereby discovering errors more quickly after they occur.

This tradeoff between the efficiency of end-to-end acknowledgements at the highest level and the more responsiveness gained by lower level validation procedures is nothing but a new form of the throughput-delay tradeoff typical of virtually all communication systems. In the Packet Radio context this tradeoff has been analyzed in [GITMAN, 1976].

1.2 THE PACKET RADIO SYSTEM

We consider a Packet Radio System (broadcast data network) designed to provide local collection and distribution of data over large geographical areas. The system should be economical, reliable, secure, and conservative of spectrum.

This Packet Radio Network (PRNET) includes three logical devices:

- Packet Radio Terminals,
- Packet Radio Stations, and
- Packet Radio Repeaters. (See Figure 1.3)

The Packet Radio Terminal consists of: (1) a device which sends or receives digital data; this includes TTY like devices, CRT Terminals, sensors generating digital information, personal digital terminals, digital voice terminals, display terminals and computers micro, mini, and maxi; together with: (2) an interface to the rest of the Packet Radio Network.

The Packet Radio Station performs accounting, buffering, directory, and routing functions for the overall system. In some applications the Packet Radio Station will also be the interface component ("Gateway") between the broadcast system and an external point-to-point network (Figure 1.3). As such it will have broadcast channels into the Packet Radio System and link channels into the point-to-point network.

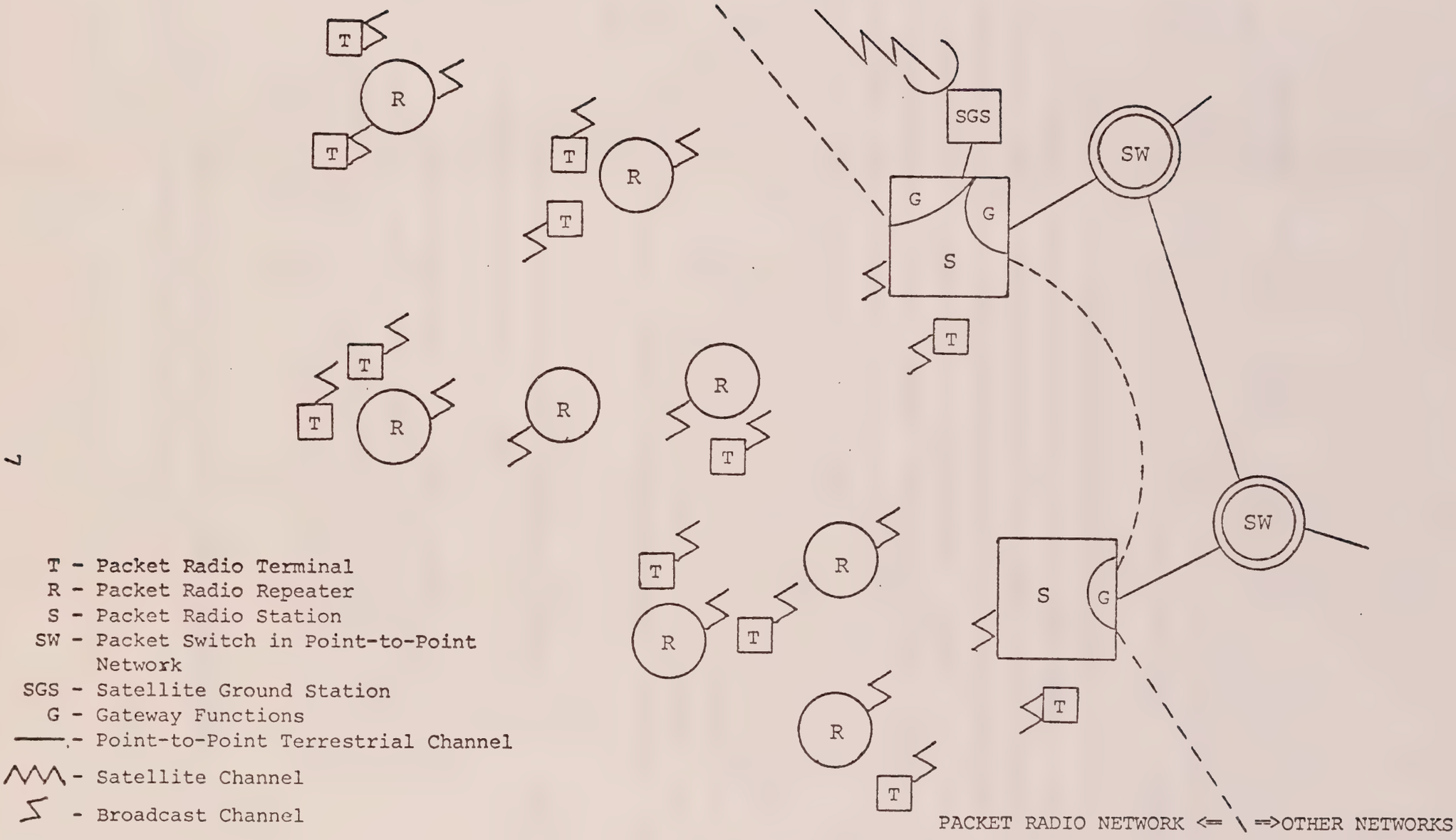

FIGURE 1.3: PACKET RADIO NETWORK

The basic function of the Packet Radio Repeaters is to provide a network for connection of terminals to one or more stations, thereby increasing the size of the area that can be served by a station and providing paths to alternate stations to insure reliable communications.

The physical implementation of these logical devices is based on the Packet Radio (PR) which is an RF transceiver together with a microprocessor, operating system, and appropriate interfacing electronics. In their simplest manifestations a Packet Radio Terminal is realized as a digital data I/O Device linked to a PR which acts as the interface to the PRNET; the Packet Radio Repeater as a stand alone PR; and the Packet Radio Station as a minicomputer and a PR acting as the interface to the PRNET. A PR can serve simultaneously as a repeater and part of a terminal. The PR is a versatile and general radio data communication device in that its logical function can be easily changed by reprogramming the microprocessor.

The main features which distinguish the Packet Radio System from a point-to-point packet switching system (such as the ARPANET) are:

1. Devices in the system transmit packets by using a random access scheme, and

2. Devices broadcast so that packets can be transmitted to several devices simultaneously, and/or several packets can be simultaneously received by a receiver because of independent transmissions of several devices.

These features make the packet radio technology particularly suitable for applications in which:

A. Terminals are mobile, so that a broadcasting mode is necessary

B. Terminals are located in remote or hostile locations where hardwire connections are not feasible

C. Terminals have a high ratio of peak bandwidth to average bandwidth requirements (because the random access method allows the dynamic allocation of channel capacity without centralized control)

D. Terminals require little communication bandwidth so that hardwire connections are uneconomical.

1.3 PACKET RADIO NETWORK COMMUNICATION PROTOCOLS

A broad classification of PRNET protocols is given in this section. It is useful to classify protocols into hierarchy levels and/or according to clearly defined functions, because it enables one to associate a particular protocol (or function) with a hardware and/or software module which uses the protocol. Protocol classification also enables the design of nonoverlapping sections of the packet (or packet headers) and association of each section with a function or protocol. This is particularly useful when a packet traverses different media (networks) since by properly placing the various headers it enables one to strip off a header which is no longer needed or add a new header when needed so as to minimize packet overhead. Finally, protocol classification enables one to assign hardware and/or software development responsibility to different groups, minimizing interfacing problems.

The protocols used by the PRNET communication devices can be classified into three hierarchy levels associated with the traversing of a packet over a single hop, over the PRNET, and between processes of the end devices. These three levels can be further subdivided into functions of operation, validation, and initialization and maintenance.

Level I:	Inter PR Protocols
Level II:	Terminal Station Protocols
Level III:	Inter Process Protocols

The inter PR (Packet Radio) protocols include all the procedures applied to a packet from the time it is read out of a PR buffer for transmission until the end of packet transmission and resetting of PR parameters, and the procedures used from the time a packet is detected (including the detection process) until the packet is written into a PR buffer and PR parameters are reset. This level also includes the protocols which govern communication between a terminal, station, or host and its PR. In terms of the model depicted in Figure 1.1, the transmitters and receivers are PR's and the channel is the ordinary broadcast channel used by the devices in the first case. In the second case the transmitting and receiving devices are either a station, host, or terminal and a PR. The channel will ordinarily be a wire.

The terminal - station protocols are concerned with the efficient and reliable transport of packets between stations and terminals, stations and repeaters, and possibly stations to stations through the Packet Radio Network. Included are routing functions, flow control in the Packet Radio Network, verification of correct transmission, initialization and control, management and measurement of network operation and performance. In this case, the receivers and transmitters are terminals, hosts, or possibly the associated PR's depending on the implementation itself. The corresponding protocol in the ARPANET is where the transmitters and receivers are the origination and destination IMP's (or TIP's) in the communication, and the "channel" is the ARPANET itself. In neither case, does this level of protocol take any cognizance of the mechanism by which the message traverses the hops or links within the network.

The inter process protocols is the class used between the programs or processes of the origination device and programs or processes of the destination device; either of which or both may be in the packet radio network. These protocols establish and maintain the connection between the end processes, and include the set of rules for the exchange of messages between the particular end processes. An example of such a protocol is the INTERNET protocol of Cerf and Kahn [CERF, 1974], [CERF, 1975]. The inter process protocols are transparent to the packet radio repeater and to the section of the packet radio terminal and station which interface with the PRNET. Figure 1.4 shows schematically, the Protocol Levels for the PRNET.

Protocols are reflected in the packet as packet headers; the term "header" is used even though the information appears both at the beginning and the end of the packet. It is logically most consistent that the protocol information goes from the lowest to highest level from the outside of the packet to the inside. Figure 1.5 is a schematic of a proposed PRNET packet.

Ordinarily, in each of the three levels of hierarchy the "a" part of the header includes such information as the size of the packet, its type relative to the protocol level in question, and possibly its position in a sequence scheme. Ordinarily the "b" part contains a checksum for the appropriate level.

Let us briefly follow a packet from sending process to receiving process to see what happens to the header in transit. For concreteness we will assume that the sending process is in a PR terminal and the receiving process is a host on the ARPANET. The initiating process passes the text along with the Level III header to the terminal. The terminal may subdivide the text into smaller packets and append the Level II header. The original text (or piece of it) and the Level III header will appear to the Level II protocol as undifferential "text". That is, the Level III header will not be recognized. Then the terminal

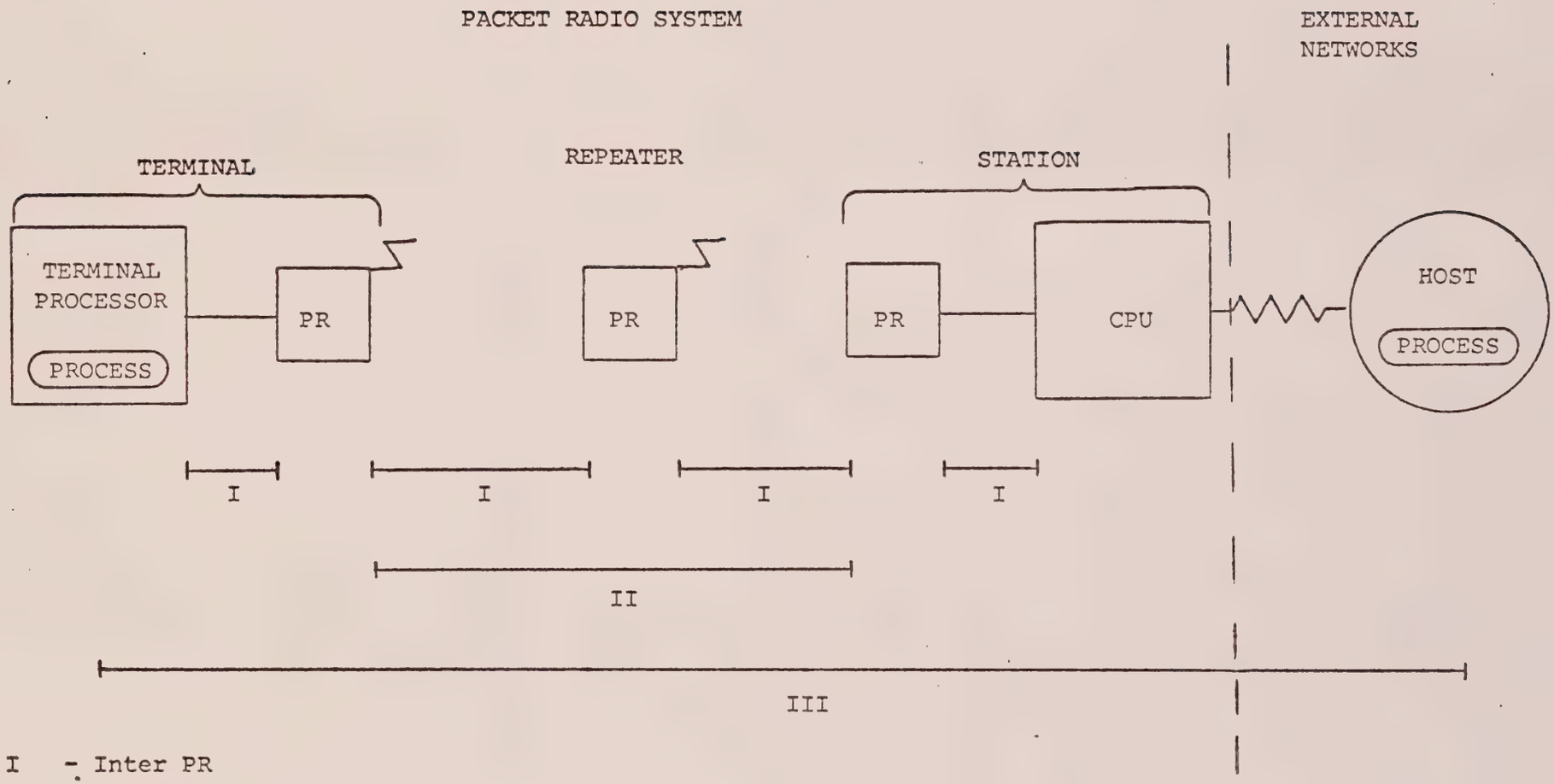

FIGURE 1.4: COMMUNICATION PROCEDURES HIERARCHY

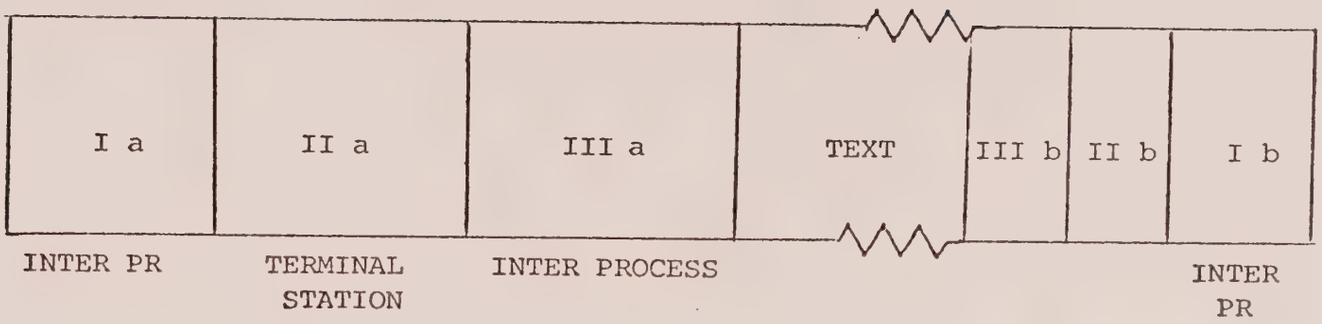

FIGURE 1.5: PACKET SCHEMATIC

attaches a Level I header corresponding to the protocol for the interface between terminal, host, or station and its associated PR. At the PR the Level I checksum is verified if present and the old Level I header is taken off the packet and a new Level I header which will in general have a different format corresponding to a Packet Radio hop - i.e., Inter PR - is added. Eventually, the packet(s) reach a gateway to the ARPANET. At this point, the Level II header is replaced by the Level II header appropriate to the ARPANET (also, the format of the Level I header changes to the link protocol format of the ARPANET at this point). Finally, the host is reached, the message reassembled and the Level III checksum (if present) can be verified. Note that the Level III checksum offers end-to-end validation, however in general (especially if the packets are divided) the sum cannot be verified until the very end of the transmission. If the PRNET turned out to be very unreliable, and the delay in the ARPANET very long (say because of satellite channel delays) this could lead to very long expected delay time. In this situation one would certainly also want Level I or Level II checksums.

If the headers corresponding to the different levels are configured as in Figure 1.5, then each level checksum is not disturbed by changes in lower level header fields.

Unfortunately, the idealized partition implied by Figure 1.5 is often very expensive in bits of header required. In practice, many fields are shared by the various levels. For example, if the headers of the various levels have a length known to each level protocol only, one packet length field is necessary. It can be shared by all levels.

1.4 REFERENCES

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